

FINAL REPORT
OF THE
SPACE SHUTTLE
PAYLOAD PLANNING WORKING GROUPS

Executive Summaries

MAY 1973

NATIONAL AERONAUTICS & SPACE ADMINISTRATION
GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland 20771

FOREWORD*

In January 1972 the United States decided to develop a new space transportation system, based on a reusable space shuttle, to replace the present expendable system.

By January 1973 planning had progressed to the point that through the European Space Research Organization (ESRO) several European nations decided to develop a Space Laboratory consisting of a manned laboratory and a pallet for remotely operated experiments to be used with the shuttle transportation system when it becomes operational in 1980.

In order to better understand the requirements which the space transportation must meet in the 80's and beyond; to provide guidance for the design and development of the shuttle and the spacelab; and most importantly, to plan a space science and applications program for the 80's to exploit the potential of the shuttle and the spacelab, the United States and Europe have actively begun to plan their space programs for the period 1978-1985, the period of transition from the expendable system to the reusable system. This includes planning for all possible modes of shuttle utilization including launching automated spacecraft, servicing spacecraft, and serving as a base for observations. The latter is referred to as the sortie mode. The first step in sortie mode planning was the Space Shuttle Sortie Workshop for NASA scientists and technologists held at the Goddard Space Flight Center during the week of July 31 to August 4, 1972. For the purposes of that workshop, shuttle sortie missions were defined as including those shuttle missions which employ observations or operations (1) from the shuttle itself, (2) with subsatellites of the shuttle, or (3) with shuttle deployed automated spacecraft having unattended lifetimes of less than about half a year.

In general the workshop was directed towards the education of selected scientific and technical personnel within NASA on the basic capabilities of the shuttle sortie mode and the further definition of how the sortie mode of operation could benefit particular disciplines. The specific workshop objectives included:

- Informing potential NASA users of the present sortie mode characteristics and capabilities
- Informing shuttle developers of user desires and requirements
- An initial assessment of the potential role of the sortie mode in each of the several NASA discipline programs
- The identification of specific sortie missions with their characteristics and requirements

*Reprinted from the volume entitled "Executive Summaries".

- The identification of the policies and procedures which must be changed or instituted to fully exploit the potential of the sortie mode
- Determining the next series of steps required to plan and implement sortie mode missions.

To accomplish these objectives 15 discipline working groups were established. The individual groups covered essentially all the space sciences, applications, technologies, and life sciences. In order to encourage dialogue between the users and the developers attendance was limited to about 200 individuals. The proceedings were, however, promptly published and widely distributed. From these proceedings it is apparent that the workshop met its specific objectives. It also generated a spirit of cooperation and enthusiasm among the participants.

The next step was to broaden the membership of the working groups to include non-NASA users and to consider all modes of use of the shuttle. To implement both objectives the working group memberships were expanded in the fall of 1972. At this time some of the working groups were combined where there was appreciable overlap. This resulted in the establishment of the 10 discipline working groups given in Attachment A. In addition European scientists and official representatives of ESRO were added to the working groups. The specific objectives of these working groups were to:

- Review the findings of the GSFC workshop with the working groups
- Identify as far as possible the missions (by mode) that will be required to meet the discipline objectives for the period 1978 to 1985
- Identify any new requirements or any modifications to the requirements in the GSFC report for the shuttle and sortie systems
- Identify the systems and subsystems that must be developed to meet the discipline objectives and indicate their priority and/or the sequence in which they should be developed
- Identify any new supporting research and technology activity which needs to be initiated
- Identify any changes in existing procedures or any new policies or procedures which are required in order to exploit the full potential of the shuttle for science, exploration and applications, and provide the easiest and widest possible involvement of competent scientists in space science
- Prepare cost estimates, development schedules and priority ranking for initial two or three missions

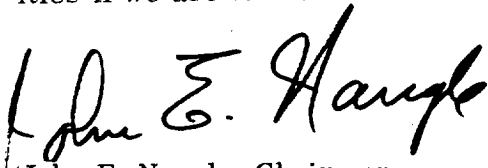
In order to keep this planning activity in phase with the shuttle system planning the initial reports from these groups were scheduled to be made available by the spring of 1973. It was also felt necessary that the individual working group activities be coordinated both between the groups and with the shuttle system planning. As a result, the steering group given in Attachment B was established.

Early in 1973, NASA and the National Academy of Sciences jointly decided that it would be appropriate for a special summer study to review the plans for shuttle utilization in the science disciplines. This summer study has now been scheduled for July 1973. It is anticipated that the results of the working group activities to date will form a significant input into this study.

In the following sections of the summary document are the executive summaries of each of the working group reports. While these give a general picture of the shuttle utilization plan, the specific plan in each discipline area can best be obtained from the full report of that working group. Each working group report has been printed as a separate volume in this publication so that individuals can select those in which they are particularly interested.

From these working group reports it is apparent that an appreciable effort has been made to exploit the full capability of the shuttle. It is, however, also apparent that much work remains to be done. To accomplish this important work, the discipline working groups will continue.

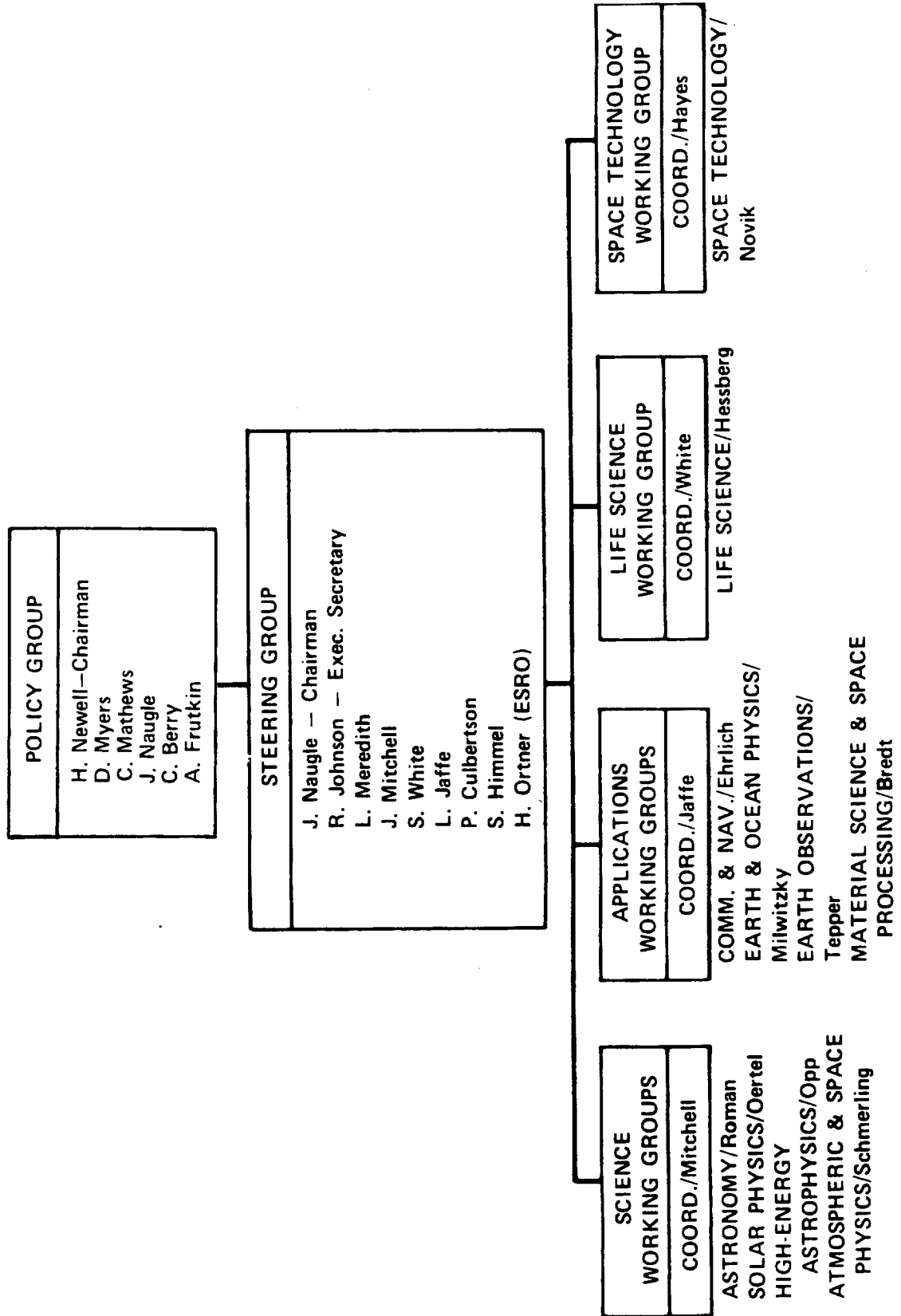
Finally it is evident from these reports that many individuals and groups have devoted appreciable effort to this important planning activity. I would like to express my appreciation for this effort and stress the importance of such activities if we are to realize the full potential of space systems in the 1980s.


John E. Naugle, Chairman
NASA Shuttle Payload Planning
Steering Group

LIST OF WORKING GROUPS

<u>GROUP NAME</u>	<u>CHAIRMAN</u>	<u>CO-CHAIRMAN</u>
1. ASTRONOMY	Dr. N. Roman (HQ)	Dr. D. S. Leckrone (GSFC)
2. ATMOSPHERIC & SPACE PHYSICS	Dr. E. Schmerling (HQ)	Mr. W. Roberts (MSFC)
3. HIGH ENERGY ASTROPHYSICS	Dr. A. Opp (HQ)	Dr. F. McDonald (GSFC)
4. LIFE SCIENCES	Dr. R. Hessberg (HQ)	Dr. D. Winter (ARC)
5. SOLAR PHYSICS	Dr. G. Oertel (HQ)	Mr. K. Frost (GSFC)
6. COMMUNICATIONS & NAVIGATION	Mr. E. Ehrlich (HQ)	Mr. C. Quantock (MSFC)
7. EARTH OBSERVATIONS	Dr. M. Tepper (HQ)	Dr. W. O. Davis (DoC/NOAA)
8. EARTH AND OCEAN PHYSICS	Mr. B. Milwitzky (HQ)	Dr. F. Vonbun (GSFC)
9. MATERIALS PROCESSING AND SPACE MANUFACTURING	Dr. J. Bredt (HQ)	Dr. B. Montgomery (MSFC)
10. SPACE TECHNOLOGY	Mr. D. Novik (HQ)	Mr. R. Hook (LaRC)

NASA AD HOC ORGANIZATION FOR SHUTTLE PAYLOAD PLANNING



CONTENTS

	<u>Page</u>
ASTRONOMY	1
ATMOSPHERIC & SPACE PHYSICS	5
HIGH ENERGY ASTROPHYSICS	9
LIFE SCIENCES	13
SOLAR PHYSICS	17
COMMUNICATIONS & NAVIGATION	23
EARTH OBSERVATIONS	25
EARTH AND OCEAN PHYSICS	31
MATERIALS PROCESSING AND SPACE MANUFACTURING	37
SPACE TECHNOLOGY	39

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ASTRONOMY WORKING GROUP

EXECUTIVE SUMMARY

The principal advantages of space astronomy over ground-based observations reside in the greatly increased spectral coverage and angular resolution attainable from above the earth's atmosphere. For the first time celestial objects can be studied over virtually the entire electromagnetic spectrum from radio to gamma-ray frequencies. Even at the present early stage, this ability has produced a number of major surprises - for example, the overwhelming infrared emission from a variety of objects including planetary nebulae and galactic nuclei. Higher angular resolution will not only permit more detailed study of the structure of individual objects but, because of night sky suppression, will also allow observation of substantially fainter and hence more distant sources. By exploiting these advantages during the coming decades we will be able to solve, or at least to greatly increase, our understanding of such major scientific problems as the evolution of the early universe, the nature of quasars, galactic nuclei and radio sources, the formation of galaxies and of the stars within them, the origin of the chemical elements, and the origin of the solar system and of life itself. Solutions to these problems will impact all branches of human endeavor that have been seriously hampered in the past by the limited view of the universe available from the ground.

The immense potential of space astronomy has been amply demonstrated during the last decade with comparatively small, exploratory instruments, limited to the observation of relatively bright sources. The time is now appropriate to establish in space the full range of observing facilities required to solve long-standing astronomical problems. The advent of the Space Shuttle renders this not only technically feasible but even moderately inexpensive as compared to earlier ventures in space science.

The cornerstone of our recommendations for the 1980's is the Large Space Telescope (LST), a three meter aperture, diffraction-limited telescope optimized for the ultraviolet and visible regions of the spectrum but usable also in the infrared. It will be operated as an automated satellite and will be periodically serviced by the Shuttle. The LST will extend significantly the distance to which we are able to probe the universe and offers, for example, a prospective solution to the cosmological problem, which has not proved possible from the ground. A balanced program requires that this major instrument be supplemented by other more specialized instruments, as indeed are also required in ground-based observatories.

Because the LST is not planned primarily for the infrared, early emphasis in the Shuttle Sortie program is placed on this spectral region. Two infrared telescopes are proposed.

- A 1.5-meter aperture telescope, cryogenically cooled to about 20° K specifically for the 10-50 μ m wavelength region.
- A very large uncooled telescope for the far-infrared and microwave region, and for planetary studies and narrow-band spectroscopy over the whole infrared range.

Although both telescopes could operate as automated free-flyers based on the same spacecraft Support System Module (SSM) developed for the LST, both would gain by operation on the Shuttle. For the uncooled telescope the Shuttle allows the accommodation of larger optics than would be possible with the Titan-compatible SSM, as well as the possibility of interchanging instruments at the focal plane during flight. The cryogenic system for the cooled telescope would be much simpler and less expensive on the Shuttle. These telescopes will be powerful tools in the exploration of such diverse phenomena as the immense infrared energy output of galactic nuclei, the conditions in the interstellar medium leading to star formation, and the physical properties and composition of planetary atmospheres and surfaces.

In the ultraviolet, there is a definite need for a wide angle telescope to provide a UV survey in one broad wavelength band if the LST is to be used for many years to maximum effect. Subsequent use for studies at different wavelengths or for an ultraviolet spectral survey would be valuable but less urgent. A one meter diffraction-limited telescope for the ultraviolet and visible will provide high angular resolution imaging over relatively wide fields of view (0.5°). Such a capability is required, for example, for photometric studies of stellar evolution in globular and open clusters and to supply observations of nearby galaxies as the basis for LST studies of faint ($> 21^m$) extragalactic sources. Unless or until the LST makes possible the frequent monitoring of solar system bodies, the 1-meter telescope can provide the needed synoptic coverage. The major advantage of the Shuttle for both these instruments is that it will allow use of photographic and electronographic detectors with their very large information storage capability. The 1-meter telescope will also provide an important test bed for auxiliary instrumentation for LST, allow specialized observations of a "one-of-a-kind" nature and relieve LST of observations of relatively bright sources.

In addition to these five instruments, which the panel considered in detail, several other instruments which were considered briefly are typical of those which the Shuttle program should include. Examples are a very wide angle ultraviolet camera for the study of large scale, low surface brightness nebulae and star

clouds, a grazing incidence telescope for the extreme ultraviolet between the normal X-ray region and the Lyman limit of hydrogen, Explorer-class free flyers (to measure the cosmic microwave background for example), and rocket-class instruments which can fly frequently on a variety of missions.

Except for the LST, each of the major astronomy instruments requires approximately half of the space, weight, and other support of a Sortie flight. While each could be operated remotely from the ground, our present impression is that in most cases it would be preferable to have the support of a four man Shuttle crew, in addition to the pilot and co-pilot, and a small laboratory to provide workspace, data storage, communications and access to the focal plane of at least one telescope. Although the individual instruments could share a Sortie mission with another discipline, compatibility requirements are severe. Astronomy requires stabilization of the Shuttle to near one arc minute (by means of control moment gyros), control of the pallet pointing direction throughout operation as dictated by the astronomical program, and a contamination-free environment. We therefore believe that we would be our own best companion. Most scientific direction must be from the ground, making it necessary to have excellent communication, including picture transmission, on both up and down links. A data relay satellite would be very helpful, although astronomy can use the intermittent communication provided by a ground network of tracking stations if adequate capacity compensates for limited time and if real-time communications are possible from the receiving station to a central control station at the same rate.

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ATMOSPHERIC & SPACE PHYSICS WORKING GROUP

EXECUTIVE SUMMARY

OBJECTIVES

Three major objectives have been defined for the discipline in the Shuttle decade of the 1980's:

- Investigate the detailed mechanisms which control the near-space environment of the earth.
- Perform plasma physics investigations not feasible in ground-based laboratories.
- Conduct investigations which are important in understanding planetary and cometary phenomena.

In defining these objectives it has been assumed that the ongoing Explorer series of spacecraft — including the IMPs, the IME, the Atmosphere Explorers, and their follow-ons, especially the Electrodynamic Explorers — will have accomplished by 1980 the major task of surveying and cataloguing all the gross features of the near-earth interplanetary medium, the magnetosphere, and the upper atmosphere. Thus, the task for the 1980's will be to understand the dynamical processes of the sun-earth system, and to explore the cause-and-effect relationships. Most of this work can be best accomplished by short-term, definitive, active experiments which are ideally suited to the 7-30 day Shuttle Sortie mode of operation.

EXPERIMENT CONCEPTS

The major experiments which have been envisioned thus far for the 1980's all involve the Shuttle. These are:

ACTIVE EXPERIMENT — SHUTTLE AS OBSERVING PLATFORM

The release of a tracer (e.g. lithium) outside the magnetosphere, and the use of a Shuttle with diagnostic instruments can resolve rather directly the question of what fraction of the solar wind enters the forward magnetosphere near the neutral points, and what fraction enters through the tail.

ACTIVE EXPERIMENT — SHUTTLE AS SOURCE

The Shuttle can paint a significant fraction of an entire orbit with a chemical such as barium. Observing this trail — using aircraft and ground-based cameras — could provide more information on global circulation than many years of sounding rocket releases.

The use of an electron accelerator to generate an artificial aurora — to be observed on the ground or from aircraft — could provide definitive answers to the acceleration mechanism and plasma instabilities.

The stimulation of plasma resonances — to be observed from a sub-satellite — can provide immediate answers to basic questions of interaction volumes and resonant Fourier structure.

SHUTTLE AS PLASMA LABORATORY

The maximum power which can be pumped into an antenna before the process becomes self-limiting due to non-linear effects can be readily investigated in a number of plasma and radio-frequency regimes which cannot be modelled in a plasma chamber on the ground.

SHUTTLE AS PERTURBATION

The electromagnetic wake behind a Shuttle can be mapped with a maneuverable sub-satellite. Both the real wake (including out-gassing) and the pure electromagnetic wake from a clean test body can be mapped in detail.

SHUTTLE AS AN ATMOSPHERIC SCIENCE FACILITY

Gaseous reactions and excited states can be investigated by releasing kilograms of gas. These can be excited by the Sun, by laser beams, or by electron beams, and the reactions observed by instruments on the Shuttle or a sub-satellite.

SHUTTLE FOR WAVE-PARTICLE INTERACTIONS

To investigate wave/particle interactions using particles and waves generated on board, with those generated from the ground or found in-situ. These range from weak interactions to those strong enough to produce large perturbations in the radiation belts.

SHUTTLE AS A CIRCUIT-BREAKER

By releasing electron acceptors (such as sulfur hexafluoride) over the electrojet, it is possible to reduce conductivities sufficiently to stop the equatorial or auroral electrojet for times of the order of minutes. This will enable basic questions of electrodynamics to be investigated. Ground-based and rocket diagnostics will be needed.

SHUTTLE AS A PRECIPITATOR

The addition of small amounts of cold plasma at certain locations in the magnetosphere can produce rapid growth of wave instabilities and subsequent dumping of large amounts of trapped particles into the atmosphere. Shuttle experiments designed to release such plasma can point the way toward active control of the radiation content in the Van Allen belts.

LABORATORY CONFIGURATIONS

Prior to the formation of the Atmospheric and Space Physics Working Group, three separate studies had been initiated along traditional discipline lines to explore the needs of the various segments of the scientific community relative to the Shuttle. These resulted in separate requirements for three distinct Shuttle laboratories:

- A Plasma Physics and Environmental Perturbation Laboratory (PPEPL)
- An Atmospheric Science Facility (ASF)
- A Magnetosphere and Auroral Manned Observatory System (MAMOS).

This report thus represents a distillation of the ideas provided by about 300 contributors. When the Working Group came into being in late 1972, it was realized that the three facilities could profitably be combined into one module. A great economy of instrumentation could be obtained by recognizing, for example, that the electron gun on the PPEPL could provide an electron excitation source for ASF and MAMOS; that the concept of gas release cylinders on PPEPL could be used in conjunction with a laser to greatly enhance the study of atmospheric reactions on ASF; and that the sub-satellite required for the MAMOS key mission was similar in many respects to the subsatellite required for PPEPL.

The Working Group concluded that nine basic pieces of core instrumentation would form the building blocks for Sortie laboratories. Arranged in various

configurations on the Sortie pallets, these would be used interchangeably on missions optimized for Magnetosphere, Atmosphere, or Plasma Physics Studies. A key finding is that the use of a small number of core instruments, flown repeatedly to perform many different experiments, results in a low-cost, economical approach to performing the needed research.

FLIGHT SCHEDULES

In order to perform most of the experiments which have been suggested thus far in these laboratory configurations, a flight program on the order of four Sortie flights per year over the decade of the 1980's is required, if each flight is assumed to be seven days in duration and two crew members are available to perform experiments. Thus, one or two dedicated Sortie laboratory shells will be required, and two pallets for instrument mounting. This would permit a six-month turn-around time for refurbishment of each laboratory between launches. It is felt that such a program, together with the ongoing Explorer series, should be able to answer most of the key scientific questions for the discipline in the 1980's, and that this approach achieves real economies by reflying the same group of instruments many times with only minor changes.

HIGH ENERGY ASTROPHYSICS WORKING GROUP

EXECUTIVE SUMMARY

High energy astrophysics is an important and critical part of the present exciting and explosive growth of our knowledge of the cosmos. It is conducted of necessity from space because the earth's atmosphere absorbs the X-rays, γ -rays, and cosmic rays to be observed. It has profoundly influenced other areas of astrophysics as well as areas of fundamental physics. For instance, the discovery by Uhuru of X-ray binary stars, one or more of which may contain a "black hole" has instigated many theoretical and observational studies of binary systems and of the final compact states of stellar evolution. The existence of black holes would, in certain respects, be the equivalent for general relativity to what the existence of very energetic particles has been for special relativity.

High energy astrophysics is the study of energetic processes within or near compact objects (galaxies, binary stellar systems, quasars, pulsars) and in the diffuse matter between these objects (interstellar hydrogen, the gaseous remnants of supernova and intergalactic space). The field deals with the most energetic and transient phenomena in the Galaxy and Universe. This is apparent from the time scales of these processes, which tend to be short compared to the galactic or Hubble time scale of $\sim 10^{10}$ years. The high energy particles involved are generally not in thermal equilibrium with the surrounding medium and tend to lose energy rapidly or to escape from a region of confinement (10^6 years for galactic cosmic rays; ~ 1 year for electrons giving rise to X-rays in a supernova remnant). Also the events which accelerate the particles or modulate the observed photons are often of short duration (~ 1 hour for a binary eclipse of an X-ray star, ~ 1 sec for stellar collapse, 33 msec for the rotation of a neutron star, 10 - 100μ sec for the predicted fluctuations of emission from a black hole).

Cosmic rays detected at the earth (protons, electrons, nuclei) are direct samples of the particles participating in the energetic events. X-rays are emitted by these high energy electrons via processes such as synchrotron radiation and thermal bremsstrahlung. Gamma rays are emitted by nuclear processes such as the decay of excited nuclei or elementary particles (e.g. π^0) created in proton-proton collisions. In general the scale of the interaction region is set by the energy of the observed photons. Quanta of visible light come from the outer shells of atoms. X-rays quanta come from the inner shells of atoms, closer to the nuclei. Gamma rays of medium energy come from within the nuclei themselves, and gamma rays of high energy come from the individual elementary particles out of which nuclei are made.

The most dramatic recent discoveries have been in X-ray astronomy and have come from the Uhuru satellite (2-20 keV). The discoveries of binary X-ray

stars and diffuse X-ray sources within clusters of galaxies are clearly of fundamental importance. These phenomena alone can be the basis of much future research in X-ray astronomy. Also, we know that young and old supernova remnants, active radio galaxies, a quasar, one (and possibly two) pulsars and at least one Seyfert galaxy, are X-ray emitters. The third Uhuru catalog contains ~ 160 galactic and extragalactic sources. Since the X-rays usually carry a dominant portion of the emitted electromagnetic radiation, studies of this portion of the spectrum are critical to our understanding of these objects.

High energy γ -ray observations have taken on new significance and give promise for major advances with the dramatic discovery of a "ridge" of emission centered on the galactic plane. The emissions are probably due to the production and subsequent decay of π mesons by cosmic rays impinging on the interstellar gas. Discrete γ -ray lines in the MeV range have been measured during intense solar flares. Confirmation of such lines from cosmic sources will open the whole field of observational nuclear astrophysics. An apparently isotropic flux of diffuse γ -rays has been measured over the entire range from ~ 1 keV to 100 MeV. Although complete observational understanding of this complex multicomponent phenomena has not yet been accomplished, it is clear that the total picture will have profound cosmological significance.

Cosmic ray research has focused upon measurements of the charge and energy spectra of its different components (nuclei and electrons). Until very recently the elements were well measured only up to about 10 GeV/nucleon and all components appeared to have similar spectra. In the last two years, however, new measurements in the region above 10 GeV/nucleon have revealed interesting spectral differences between the "secondary" elements (such as Li, Be, B), which probably result from interstellar spallation, and the "primary" elements (such as C, O). In addition, the spectrum of iron appears to differ from that of carbon and oxygen. Detailed analysis of these spectral differences provides us with unique information about the generation, acceleration, and propagation of cosmic rays, and the role they play in galactic dynamics. Individual spectra for the low mass isotopes are also required, since in this form the effects of generation, acceleration, and propagation can be separated. Analysis of the spectra of radioactive isotopes provides a means of direct dating for the cosmic rays. Present experiments have just begun to make isotopic separation. Many of the isotopes to be measured are of low intensity and hence require large area detector systems with long integration times and high discrimination to separate the rare isotopes from their more abundant neighbors. Substantial new progress requires these capabilities. The charge spectrum of high Z cosmic rays is also important as a means of testing concepts of nucleosynthesis. The low flux of high Z cosmic rays requires large area detectors, such as can be carried on the Shuttle, to obtain statistically significant spectral data.

The above examples illustrate the commonality of the astrophysical phenomena of interest to the three subfields of High Energy Astrophysics. The three subfields are at different stages of development and require different types of facilities. This situation has arisen in part because of the relatively low fluxes of γ -rays and certain components of cosmic rays. The interstellar magnetic fields which confine the cosmic rays within the galaxy also diffuse the cosmic rays so the observed individual sources cannot be resolved by virtue of their arrival directions or arrival times. Observations of photons (e.g. X-rays and γ -rays) on the other hand yield temporal and angular information about the source particles. The actual emission process and its physical parameters must be inferred indirectly from this information together with spectral and, in the case of X-rays, polarimetry data.

The working group studied the discipline objectives in a post-HEAO scientific climate within the constraints of the shuttle system. The Working Group finds that an operational Space Shuttle would be a major stimulus to High Energy Astrophysics, given sufficient resources on a timely basis to develop the necessary instrumentation. Fundamental next-generation measurements in the three subdisciplines (X-ray, γ -ray, cosmic ray) can be carried out by making use of the large weight/area capability of the shuttle. These can and should be accomplished at low cost through a management philosophy modeled, in so far as is reasonable, after the present sounding rocket and balloon programs. Relaxed quality assurance and reliability requirements, minimal external monitoring with a correspondingly greater responsibility placed on the experimenter, and the reuse of common hardware among investigators, should be key factors of such a program.

The requirement for long observing times dictates that the major use of the Shuttle Orbital Sortie will be for the ejection and periodic recovery for refurbishment of free-flying satellites. Most of the requirements of the discipline can be served by a somewhat enlarged standardized mini-HEAO. An important usage will also be made of smaller satellites and of large area passive cosmic ray detectors. The major X-ray telescope facility given high priority herein will require a significantly larger and more specialized spacecraft vehicle. Unattended pallets in the shuttle are important in that they provide the means to make observations of specific celestial objects and to test new instruments and techniques in space. Launches of interplanetary probes out to 10 A.U. are also proposed for cosmic ray and long baseline X-ray observations.

The interaction of man with the experiments aboard the shuttle was discussed extensively. Astrophysics experiments are now routinely designed to operate in space and existing automated technology can be used to perform most of the envisioned required tasks. It is possible that a man in EVA can correct an occasional malfunction, or perform on-board monitoring of an experiment. New,

presently unconceived experimental tasks may also develop as the Shuttle program evolves. It is imperative however that the experiments should be designed and built to relaxed automated standards in order to avoid costly man rating and thus to maintain minimal experiment cost. The experiments presently envisioned are best performed on unattended pallets or free flyers.

LIFE SCIENCES WORKING GROUP

EXECUTIVE SUMMARY

INTRODUCTION

The Life Sciences Discipline is an aggregate of related research and technology including planetary biology, biomedicine, biology and advanced technology. The planning in the Life Sciences is predicated on a basic criterion that proposed areas of investigation have a space specific justification, namely, that the mechanism involved in a proposed experimental model has a gravity dependent function or there is a unique aspect to the space flight environment which precludes evaluating or testing completely the experimental hypothesis in ground-based research. The plan is a valuable overview of the scope of the Life Sciences potential payload planning developed in sufficient detail to permit subsequent programming which involves definitive engineering, hardware requirements, schedules and costs.

OBJECTIVES

Continue the research directed at understanding the origin of life and the search for extraterrestrial evidence or precursors of life.

Continue the biomedical research necessary to understand mechanisms and provide the criteria for countermeasures in support of manned space flight.

Continue advanced technology development on life support, protective systems and work aids to provide as near an Earth atmospheric environment for man as possible — to provide him with protection from hazards of the space environment, optimize his ability to work in space and to maintain his health.

Continue the research in biology to investigate those mechanisms observed to have changed in space on man-models wherein the investigation cannot be done on man and to study basic biological functions at all levels of organization (subcellular, cellular, system and organism) influenced by gravity, radiation and circadian rhythms; factors which are inherent in the space flight environment.

MISSIONS

Although the Life Sciences Payload Planning Group identified as highly desirable an early requirement for a 30 day capability, the plan encompasses the total

Shuttle capability of early carry-on payloads, pallet payloads and subsequently the 30 day dedicated Life Sciences Lab which will be used selectively for 7 day missions until 30 day missions are available. The following two tables display a matrix of flight opportunities by category of Life Sciences research or technology and do not reflect individual experiments.

Table 1

Payloads

Carry-On Payloads	1979	1980	1981	1982
Life Support Systems	2	2	2	
Biology (Advanced Biopack)	2	2	2	2
Medical	2	2		
Man System Integration	2	2		
Pallet Payload				
Life Sciences Research	1 launched & retrieved			
Module	1 retrieved			
Free Flying teleoperators	3	1	2	

CONSIDERATIONS

The Life Sciences represents a broad, multidisciplinary scientific population including bioengineers, biophysicists, biologists, physicians, psychologists, physiologists, radiobiologists, etc. The experiment planning interfaces with other disciplines in that Life Sciences can capitalize on the EVA planned by other groups, can obtain human performance data from many of the other manned experiments and can evaluate man-machine integration factors with almost every payload mission, including teleoperations.

The Life Sciences planning incorporates carry-on payloads in the early Shuttle flight era, uses the pallet mode for the Life Sciences Module, uses appropriate elements of the 30 day dedicated lab or 7 day missions and strongly supports an early 30 day Shuttle capability.

Table 2

Proposed Total Flight Schedule

SORTIE LAB 7/30 Days	79	80	81	82	83	84	85	86	87	88	89
BIOLOGY	4X	4X	4X	4X	4X	4X	4X	4X	4X	4X	4X
*PLANETARY BIOLOGY Planetary	XX	4X	XX	4X	4X	XXX	4X	XX	4X	XX	4X
BIOMEDICINE Models Man	XX 15X	4X 24X	4X 32X	XXX 40X	XX 60X	XX 60X	XX 60X	XX 60X	X 60X	X 60X	X 60X
ADVANCED TECHNOLOGY LSS/Protective Devices Teleoperators EVA	XXX X XX	XXX X XX	XXX X XX	XX X X	XX X X	X X X	X X X	X X X	X X X	X X X	X X X

*The original Table 8-2 has been changed to delete the Earth Orbital line under PLANETARY BIOLOGY since further study of this area has indicated there are no Life Sciences requirements for Earth Orbital experiments in PLANETARY BIOLOGY.

NOTE: The above table represents the number of flight opportunities that could be used by the discipline areas listed and not the number of experiments.

The plan identifies an inseparable interaction with the Orbiter. The food, water and waste management system is baselined in the Orbiter. Any medical experiment which would require measurement of food and fluid intake, output and sampling reacts with this subsystem of the Orbiter.

The introduction of the scientist/passenger population creates a requirement for validation of the medical standards and criteria used to select this new space flight population which is reflected in Table 2, BIOMEDICINE, Man.

The need for an on-board centrifuge to provide a 1-G control for biological experiments has been proposed. The rationale for this requirement, which has proponents and opponents, needs to be reviewed in-depth and a scientific position, pro or con, established due to the engineering complexity of incorporating a centrifuge.

SUMMARY

The Life Sciences Shuttle Payload Planning Group has developed a thorough representation of the payload areas which reflect a logical and cohesive organization of the diverse disciplines represented by Life Sciences. This plan, as any planning document should, offers an excess of candidate payloads from which orderly and selective programming can be implemented. It is anticipated that in order to serve a useful purpose, the plan will be augmented and/or modified as additional payload planning activities are completed.

SOLAR PHYSICS WORKING GROUP

EXECUTIVE SUMMARY

This report reviews the present state of knowledge of solar physics and its relevance in the wider astrophysical context. It identifies what appear to be the most promising areas for future work and examines the various ways in which the Shuttle Sortie mode can be used to meet the resulting experimental requirements. A specific solar payload with great scientific potential is proposed as a candidate for an early flight close to solar maximum. In defining this payload we have not considered the current specifications of the Shuttle or Sortie mode of operation as being absolutely fixed, but have outlined the science we would like to do and have identified the demands it places on the Shuttle and Sortie mode, together with the steps that must be taken in the coming months and years to achieve our goal.

Apart from its importance as an object for scientific study, the Sun exercises a profound influence on our planet. Without it, life would, of course, be impossible, but there are other more subtle effects on the terrestrial environment which arise from the emission of plasma clouds and energetic radiations from solar flares. The study of flares by means of space and ground based observations together can provide essential information for understanding the important terrestrial effects of solar activity. At this particular stage solar physics is in an excellent position to take advantage of dedicated Shuttle Sortie missions as part of a balanced program of research using a variety of space and ground based techniques.

Some of the instrumentation optimized for solar physics can also be used with advantage for research in other areas, such as UV, X-ray and gamma-ray astronomy, planetary atmospheres, earth atmospheric studies including the geocorona, the magnetosphere, and pollutant concentration levels, as well as lunar libration point studies and probably still others. It would be difficult, if not impossible, to build a single instrument package optimized for studying all these disciplines. Yet many of them can be profitably explored and better understood with data obtained from a dedicated payload that has been optimized for solar physics. In this connection we hope that the Shuttle Sortie mode will provide easy access for experimenters. It should be possible to get some experiments on board on short notice, as has been the case with sounding rockets in the past.

The Working Group has not discussed in detail the question of what other discipline payloads might be compatible with a Shuttle Sortie for solar physics. It is difficult to do so when the nature of candidate payloads from other areas is

not well known. The solar physics users should meet with other users of the same specific Sortie flight as soon as possible so that the mutual interactions of the payloads can be discussed.

Following the workshop at the Goddard Space Flight Center in August 1972 the Working Group met three times. Its membership was expanded to include four ESRO members, including the Chairman of the ESRO PASOL group, who has provided particularly effective liaison between NASA and ESRO. This group, chaired by G. Oertel of NASA Headquarters with editorial assistance provided by S. Jordan of GSFC, has prepared this report.

The Shuttle Sortie Workshop has begun a dialogue between the Shuttle designers and builders and the user community. This report continues that dialogue. The Shuttle designers should report the actions taken on the recommendations that follow, make counterproposals if necessary, and consult with this group when problems arise. The Working Group considers it imperative that this dialogue continue.

The Working Group has prepared a report which consists of two parts: Part A treats the current status of solar science, its future prospects, and the organizational framework within which these goals might be realized; Part B deals with some of the required technology and the role of man. This report may be summarized as follows.

SUMMARY OF PART A

The solar physics program as a whole, rather than the Shuttle or Sortie alone, has been considered, and a plan has been developed for an orderly evolution from the seventies to the eighties. It is apparent that the scientific objectives in solar physics cannot be achieved with either space or ground based techniques alone, but require both.

A vigorous, continuing solar physics program is essential now and in the Shuttle era to:

- Allow an orderly evolution from existing programs.
- Maintain a viable solar physics community.
- Take advantage of the 1979 solar maximum.
- Develop now the instruments to fly in the eighties.

The relationship of solar physics to other disciplines such as fundamental physics, cosmology, high energy astrophysics, dynamics of stellar atmospheres, and plasma and atomic physics, as well as studies of the magnetosphere, planetary atmospheres, meteorology, and other applied areas was considered. Two types of contributions are made by solar physics: knowledge about solar phenomena will stimulate progress in some of these areas, and vice versa; instruments designed for solar observations can be used for other studies such as extinction in the earth's atmosphere and observations of cosmic objects.

Four major areas where future investigations should be more intensively conducted have been selected. They cover four important problems that solar and stellar astrophysicists are now faced with:

- The production of mechanical energy in the subphotospheric layers and its transport and dissipation in the upper layers of the atmosphere.
- The mass flux from the subphotospheric layers into the chromosphere and corona and beyond via the solar wind.
- Solar activity and its relationship to magnetic fields.
- The production of solar flares.

Some specific problems have been outlined and the relevant critical observations have been discussed. The need for a problem oriented approach and for coordinated observation over a broad spectral range has been stressed, as well as the need for improved spatial, spectral, and time resolution. It has been pointed out also that adequate absolute photometric accuracy is of extreme importance.

Four categories of Shuttle utilization have been developed. Two (classes 1. and 4.) are major evolutionary steps from existing programs, two are entirely new approaches. Each contributes uniquely to the solar physics objectives which have been identified. They are:

1. The class of experiments currently supported by OSO spacecraft requires 1 to 5 arc second pointing stability over less than one hour, and life times of the order of years. This class of experiments should be supported by a single low cost free flier in the Shuttle era, through revisits, with maintenance and substitution of experiments as appropriate. The Shuttle can also serve as a continuously available ground station, for periods of hours to weeks, to carry out special operations at high data rates or to select special targets in real time. Easy maintainability, repairability, and experiment substitution are essential in this context. It is also essential that this free flier spacecraft be developed as soon as possible for flight in 1977 or 1978, in time for the last solar maximum before 1990.

2. The next larger class of experiments will ultimately fly on a free flying Large Solar Observatory (LSO) some time in the eighties, but to do this requires developmental, verification, and sample data acquisition flights prior to commitment to LSO. The Shuttle Sortie mode is ideally suited for this purpose, provided the required interface quality can be attained in terms of weight, power, data, pointing, freedom from contamination, etc. An exciting sample Sortie payload has been developed complete with detailed interface requirements. It has the objective of studying solar activity, flares, and flare associated phenomena and consists of experiments requiring continuous solar pointing in two classes: highly sensitive high energy instruments which require only coarse pointing and are relatively insensitive to contamination; complementary instruments for infrared, visible, UV and soft X-ray spectroscopy and imaging which require fine pointing and are generally more sensitive to contamination and pointing instability.

The instruments in this payload can also attain the objectives of the ESRO solar group which are generally in the quiet sun area. This commonality of instruments is achieved through flexible data acquisition modes and offers the exciting potential of developing different parts of the payload in the U.S. and abroad for joint experimentation. It is clear that this will require assurance to foreign contributors that they will have access to the future free-flying LSO.

3. The LSO itself is envisioned as a free flying large platform for some coarse pointed and some fine pointed experiments, rather than a single large telescope of some sort. It is a development for the eighties and should be capable of handling at least the class of instruments described in the sample Sortie payload. It could evolve from the free flier if low cost growth potential is built in.
4. The fourth category features the lowest cost and is the simplest, but it is also most exciting and promising. It maintains the advantages of the current sounding rocket operation, such as short development time for new concepts, short turnaround, minimum cost, and great flexibility and potential for broad participation by students and experienced experimenters alike. The Shuttle will extend the available observing time by orders of magnitude and reduce the cost per data element by a similar factor, while providing even greater flexibility in instrument accommodation.

A support package could be evolved from existing solar pointers, such as SPARCS, for single experiments, which could be cast overboard by the Shuttle and recovered, or deployed on a boom or gimballed mount. Alternatively, a

single "pallet" type platform could support several experiments simultaneously. These alternatives should be studied as soon as possible. The Sortie lab as well as possibly the eventual deployment of an LSO will require dedicated missions. Visits to the subsatellite and the sounding rocket class experiments can take advantage of, but do not require, a dedicated mission. They should also be considered for missions dedicated to other disciplines.

A low cost, high efficiency approach is mandatory and should be a major objective of the evaluation for the Shuttle. Highest efficiency has been obtained in areas where the scientist has had maximum control and has worked under well defined, fixed funding limitations such as in the sounding rocket program. The role of the scientist must therefore be maintained or strengthened, while limiting absolutely the funds he is allowed to expend. This is likely to be practical in solar physics where a variety of instruments make up a payload rather than a single large instrument. Documentation and other requirements on the scientist must be minimal and reduced by at least an order of magnitude from present orbital programs.

The operation of all but the smallest, exploratory instruments must be in some kind of "facility mode" to provide access to the data for all qualified solar physicists. This has been achieved, for example, through guest investigator programs in OSO-I and ATM while maintaining the current flexible and proven management approach. The allocation of a fixed percentage of observing time to guest investigators will be considered, depending upon the flexibility of the payload and the duration of orbital operations.

SUMMARY OF PART B

The observational requirements were considered from three points of view: general requirements, requirements as a function of spectral regime, and requirements for new technology. Important general requirements include the need to co-align a number of separate instruments to facilitate common object viewing and the need to carry at least a simple calibration facility on the Shuttle to ensure optimum absolute photometric calibration during operation in orbit. Specific spectroscopic and photometric requirements were established for the infrared, visible, UV, XUV, soft X-ray, hard X-ray and gamma-ray spectra. The neutron flux was also discussed. A listing of needed advances in instrument technology was generated, including the development of instrumentation to provide high resolution magnetic field measurements simultaneously with the spectral data.

Several categories of space platforms were discussed. There will be a continuing need for the types of platforms currently represented by sounding

rockets, balloons, and aircraft, as well as the type featured in the OSO series of unmanned solar observatories, referred to here as semi-automated pointing platforms. All these types can be orbited and serviced efficiently by the Shuttle. In addition, moving toward the LSO of the eighties, large finely pointed and coarsely pointed platform requirements were discussed.

The role which man might be expected to fill in operating and maintaining a complex solar instrument package in the Shuttle was considered in detail, and requirements for both a Flight Scientist as well as a Technician in orbit were determined. The possibility that a single astronaut could fill both roles was also considered.

The data transmission rates for the Shuttle solar experiment were determined to vary from a peak rate of 10^7 bps over short time intervals to a steady rate which might be as much as two orders of magnitude lower. Some of the problems involved in real time viewing of simultaneous solar images were considered. The Working Group strongly endorsed use of the data relay spacecraft system.

Finally, a tabulation of anticipated flight requirements for the seventies and eighties was generated, followed by the assembly in four Appendices of further requirements and operational procedures for the four classes of experiments for Shuttle utilization described in the previous Summary to Part A.

COMMUNICATIONS & NAVIGATION WORKING GROUP

EXECUTIVE SUMMARY

The Space Shuttle Transportation System offers the Communication and Navigation (C&N), Research and Development (R&D) and operational organizations new opportunities for developing advanced space technologies and systems in a more timely manner and at lower cost than present systems.

The Shuttle Sortie Laboratory, with its capability of carrying a maximum weight of 30,000 kilograms into a low-earth orbit, will provide a new and versatile platform to conduct certain communication and navigation experiments such as: development of large, deployable antennas for future NASA missions and for communications satellites; laser communications both to another satellite for spacecraft to spacecraft (s/c-s/c) communication transfer and direct to ground stations; and radio frequency interference mapping of terrestrial noise sources. The Sortie mode also facilitates ease of comparative test evaluation between alternative subsystems (such as antenna deployment schemes) and components prior to a commitment to an automated satellite. This will provide the C&N community with a platform to conduct in-space tests of new technology prior to commitment to an automated spacecraft. The Sortie's ability to return experiments to Earth provides for an evaluation of space environmental effects on certain communications equipment (e.g., parabolic antennas).

Although the initial Laboratory mission of seven days duration will meet many of the experiment needs, early implementation of 30-day missions will provide the experimenters with more data for statistical analysis. This will be desirable in radio interference, and laser and millimeter wave propagation experiments. Prior to these longer missions, reflights of these experiments on subsequent Laboratory flights will be desired.

All C&N automated payloads considered in the 1979-1990 time period require placement into the geostationary orbit. The large weight carrying capability of the Shuttle, its multiple payload ability, and its lower cost per pound of experiment placed into space, provides an opportunity for increased launches of space vehicles to obtain the needed technical data and to develop the required communications and related space technology. The Shuttle Astronauts may be able to perform some satellite checkout in low orbit, make some subsystem adjustments, and calibrate instrumentation to ensure successful operation before leaving the satellite unattended. To provide reliable launch services and to realize the economics of the new Shuttle Transportation System (STS), the

Tug should be made available to these payloads as early as practical, and the Tug should be capable of delivering at least a 1,360 kilogram spacecraft to the geostationary orbit. In order to realize the potential capabilities of the STS to perform in-orbit checkout, in-orbit repair and retrieval of communications and navigation satellites, studies of future spacecraft configurations are required.

In conclusion, the Shuttle Sortie Laboratory, pallet design and mission profile appear capable of providing a practical means for meeting many C&N experiment data gathering needs and for developing new space technology. The Shuttle plus Tug system can place into the desired geostationary orbit all of the C&N automated payloads considered for the first shuttle decade. These missions can gather the long term data needed and develop the space systems which may lead to eventual operational space applications by new user groups, and will increase the reliability and lower the cost to present day users of space systems.

EARTH OBSERVATIONS WORKING GROUP

EXECUTIVE SUMMARY

INTRODUCTION

This report is based on Shuttle data available in January 1973. It is an analysis of how the Space Shuttle may be used to support national efforts which require observation of the earth from space. As a first report of its kind, it serves to provide a general overview and guidance for detailed mission planning and instrument design which must follow. It is a technical report, and while it does not address itself to questions of economic or social costs and benefits, it does define a set of potential applications and systems which may now be used as a basis for socio-economic studies.

The goal of all Earth Observation missions is to conduct monitoring over long periods of time of the physical state and dynamic behavior of the earth's land surface features and of the three other elements of the global environment — air, water, and ice; and to provide for the operational application of the observations. To achieve this goal, the following phased development process is required:

- Establishment of quantitative relationships between observable parameters and geophysical variables.
- Development, test, calibration, and evaluation of eventual flight instruments in experimental space flight missions.
- Demonstration of the operational utility of specific observation concepts or techniques as information inputs needed for taking actions.
- Deployment of prototype and follow-on operational Earth Observation systems.

OBJECTIVES FOR THE 1980's

The disciplines encompassed in Earth Observations are all involved in the application of space technology to the solution of terrestrial problems. They

share a number of mission characteristics. Some of the common requirements to satisfy these characteristics in Earth Observations are:

- Earth viewing capability from a stabilized platform.
- High inclination orbits or geostationary orbits.
- Orbital altitudes in the range of 400 km to 1700 km and geostationary (36,000 km).
- Global coverage for most applications.
- Repetitive viewing of same regions to identify changes with time.
- Ground and low level correlated measurements.

The goals and objectives in Earth Observations programs are intimately related to the application objectives of remote sensing of the earth from space. In general these focus on:

- Atmospheric Monitoring
- Ocean Monitoring
- Land Monitoring

The disciplines of meteorology and atmospheric environmental quality are concerned with how the atmosphere works as a complex fluid-dynamical system. The solution to these problems is feasible. The Earth Observations programs over the next decade should be focused on capabilities from space necessary to support:

- Weather Prediction
- Air Quality Assessment
- Weather and Climate Modification
- Weather Dangers and Disaster Warnings

In ocean monitoring spaceborne remote sensors will play a significant role in meeting the needs for information about the spatial and time variations of key oceanic parameters such as surface temperature, sea state, sea ice, water

color, circulation, and the relation of ocean features to meteorological prediction. The program in ocean monitoring in the 1980's should concentrate on:

- Fisheries Resources Management
- Coastal Zone Activities
- Maritime Activities
- Water Pollution Monitoring, Control and Abatement

Monitoring of resource and environmental characteristics of the land surface can be expected to increase in importance. The unique characteristics of observation from space are rapidly being demonstrated. Improvements in capability and efficiency of operation will be needed in:

- Agriculture, Forestry, Range Resources
- Mineral and Land Resources
- Land Use Classification and Changes
- Water Resources
- Mapping and Charting
- Environment Quality and Models

SHUTTLE USES FOR EARTH OBSERVATIONS

The Space Shuttle may be used to meet the objectives of the Earth Observation program in three general ways:

- To launch and place into orbit unmanned automated satellites for both research and operational purposes and eventually to retrieve and/or refurbish such satellites.
- To place instruments and scientists into satellite orbit in a Sortie mode to conduct experiments for limited periods of time.
- To perform certain operational or contingency missions with instruments carried routinely on the Shuttle Orbiter and operated either by man or in an automated mode.

The use of the Space Shuttle system to meet research and development objectives of the Earth Observations program falls into two categories:

- Limited missions: i.e., those that can be accomplished under the time and space constraints imposed by a Shuttle Sortie mission.
- Extended missions: i.e., those that require the increased time and/or orbital characteristics afforded by the Shuttle capability to launch automated spacecraft into orbit.

Typical limited R&D missions which may be performed using the Space Shuttle include development, test and optimization of new optical, IR and microwave sensors; simulation experiments which can take advantage of a low-gravity environment; and certain other micro-meteorological experiments which require this type of environment, e.g., certain cloud physics experiments.

Extended R&D missions would include the launch of experimental satellites into polar or geostationary orbits, such as Earth Observation Satellites (EOS) or Synchronous Earth Observation Satellite (SEOS), as well as certain smaller Single Purpose Earth Observation Satellites (SPEOS).

To meet operational objectives, the Space Shuttle would be used for the launch, retrieval and/or refurbishment of systems such as the operational Earth Resources Survey (ERS) satellites, the Geostationary Operational Environmental Satellites (GOES), and later the advanced Environmental Monitoring Satellites (EMS) and the All-Weather Monitor (AWM) satellites. In general, these satellites require orbits which will need the space tug or at least an injection stage. This capability may not be available until approximately 1983-4.

A tentative schedule of Earth Observation missions prior to and during the transition from conventional to Shuttle launch capability is given in the attached table.

PRINCIPAL CONCLUSIONS

- The Shuttle affords to the Earth Observation program a capability which provides for a good mix of unmanned and manned missions (in the Sortie mode).
- The Shuttle may be used to launch unmanned automated satellites into earth orbit. However, since most Earth Observation missions require a polar orbit at altitudes ranging from 400 - 1700 km, this capability will not be available until 1983-4, some four to five years after the Shuttle comes into operation. Conventional launch vehicles will continue to be required until approximately 1983-4.

- The Shuttle may be used in a Sortie mode to carry experiments into space, together with the scientists to perform them. Of particular importance to the Earth observation program will be the ability to erect large (> 100 m) antennas in space and perform experiments to perfect high resolution all-weather environmental sensing techniques. Other important techniques to be investigated in this mode would be active laser systems requiring the presence of a human operator.
- The low-g environment in the Shuttle opens up a host of new possibilities for conducting important cloud physics and fluid circulation experiments in space.
- The Space Shuttle may eventually be used to retrieve and/or refurbish unmanned automated spacecraft, which could have significant impact on launch costs and system efficiency over a period of time.

Earth Observations Working Group Mission Model

R & D	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
ERTS	X			X														
NIMBUS		X			X													
EOS						X				X		(R)						
SPEOS					X	X												
TIROS N, O				X					X									
SMS	X	X			X													
SHUTTLE LAUNCHED																		
EOS											X	X	X	X	X	X	X	X
SEOS												RF						
SPEOS							2	2	2	X	X	X	X	X	X	X	X	X
SORTIE							4	4	4	4	4	4	4	4	4	4	4	4
TIROS P															X			

OPERATIONAL	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
TIROS N, O	X	X	X	(X)	X	X	X											
ENV. MON. SYSTEM									(X)	X								
FOREIGN SMS					2													
GOES	(X)	(X)																
ERS - LOW ORBIT					X	X		X										
SHUTTLE LAUNCHED																		
EMS											X		X	X	(X)	X	X	X
FOREIGN SMS													X	X	X	X	X	X
GOES							X		X		X		X	X	X			
OSEOS																		RF
SPEOS								X		X								
ERS - LOW ORBIT												X	X	X	X	X	X	X
AWM													X	X	RF		RF	
SORTIE								X			X				X			

R = RETRIEVAL
RF = REFURBISH
() = NON ADD

EARTH AND OCEAN PHYSICS WORKING GROUP

EXECUTIVE SUMMARY

EOPAP OBJECTIVES

The primary objectives of the Earth and Ocean Physics Applications Program (EOPAP) are to merge geophysics and oceanography with space techniques to provide practical benefits in ocean dynamics monitoring and solid-earth dynamics, with the expectation of significant contributions to the forecasting of ocean-surface conditions on a global basis, and earthquake prediction.

In order to attain these objectives, certain requirements must be met, i. e. ,

- The definition of precision measurement requirements for earth and ocean physics experiments
- The definition, development, and demonstration of new and improved sensors and analytical techniques
- The acquisition of "surface-truth" data for evaluation of new measurement techniques
- The conduct of critical experiments to validate geophysical phenomena and instrumental results
- The development and validation of analytical/experimental models for global ocean-dynamics conditions and solid-earth dynamics/earthquake predictions.

SPACE SHUTTLE EXTENSION OF EOPAP

The Space Shuttle has the potential to make significant contributions to the extension of EOPAP, using both the Sortie and launch modes.

In the Sortie mode, the Shuttle provides a test bed and observational platform for development and evaluation of new instrumentation and techniques. In addition, in this mode man can be used effectively to make equipment adjustments (gain changes, frequency adjustments, etc.) to optimize matching sensor characteristics to the observables, to observe and correlate with remote sensing, and to make critical judgments as necessary to provide flexibility in the use of equipment and in programming experiments.

In the launch mode, the Shuttle can be used to launch and retrieve free-flight and tethered satellites. The Shuttle is especially advantageous for low-altitude, short-lived satellites, such as free-flying and tethered magnetometer satellites.

SHUTTLE SORTIE MISSIONS

Ocean Dynamics Test Bed

- Typical instrumentation for the ocean dynamics test bed includes the following:
 - Radar altimeter (sea-surface topography, sea state, salinity, rain)
 - Microwave scatterometer (surface roughness, wind speed)
 - Precision multifrequency coherent imaging radar
 - Multifrequency, dual polarized microwave radiometer, C and L Bands; frequencies: 1, 5, 10, 20, 50 GHz; resolution: 10 km; antenna: 4 meters (foam, wind speed, salinity, surface temperature, atmospheric corrections)
 - Vertical temperature profile radiometer
 - Laser altimeter
 - Laser profilometer
 - Laser scatterometer
 - Laser scanning photometer
 - Receiver for bistatic wave spectrum analysis
- Weight of sensors: 700 kg
- Peak power: 7 kw
- Data rate: 15 MHz
- Stabilization and pointing: 1 arc minute
- Orbit: 200 km, circular; inclination 60°
- Mission duration: 1 week to 1 month
- Flight frequency: 1 per year

Earth Dynamics Test Bed

- Typical instrumentation for the earth dynamics test bed includes the following:
 - Precision multi-frequency imaging radars (see through foliage for topographic features, geology, hidden faults, and near-surface geothermal mapping)
 - Imaging radar for double-exposure holography (3-dimensional strain fields, erosion, volcanic motion, post-glacial uplift)
 - FM correlation radar (baseline measurements)
 - Multi-frequency laser and microwave differential refraction experiment (model atmospheric, tropospheric, and ionospheric corrections)
 - Laser ranging/altimeter
 - Multispectral scanners (topographic features and geology)
- Weight of sensors: 700 kg
- Peak power: 5 kw
- Data rate: 5 MHz
- Stabilization and pointing: 1 arc minute
- Orbit: 200 km, circular; inclination: not critical
- Mission duration: 1 week
- Flight frequency: 1 per year

FREE FLIGHT SATELLITES

- Geopause-B: Precision tracking satellite for extreme-accuracy measurements to support gravity field and ocean dynamics missions. Weight: 500-1000 kg; altitude 24000 km, polar orbit.

- Gravity Gradiometer Satellites: Measure fine structure of gravity field and geoid. Weight: 3000 kg; altitude: 200 km, polar orbit.
- Minilageos: Small, dense, passive spheres covered with laser retro-reflectors for precision earth-motion studies. Weight: 100 kg; altitude: 300-1000 km, various orbital inclinations.
- Magnetometer Satellites: Low altitude vector magnetometer satellites to determine fine structure of magnetic field. Weight: 150 kg; altitude: 400 km, circular orbit; 3 satellites separated by 4-hours local time.
- Magnetic Field Monitor Satellite: Weight: 200 kg; altitude 1000-2000 km, orbital inclinations 0-28°.
- Tethered Vector Magnetometer Satellite: Weight: 150 kg; trails Shuttle by 2 miles.

MISSION MODEL

The EOPAP Mission Model, covering both the pre and post Shuttle periods, is shown in Table 1.

Table 1
Earth and Ocean Physics Mission Model

	CY	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
<u>EOPAP Satellites</u>																		
GEOS-C		1																
LAGEOS				1														
SEASAT A, B					1					1*								
GEOPAUSE							1											
GRAVSAT							1											
<u>Sortie Missions</u>																		
Test Bed Flights							1	2	2	2	2	2	2	2	2	2	2	2
<u>Shuttle Launched</u>																		
SEASAT B										1*								
Gravity Field								1		1								
Earth Motion								6					6					
Magnetic Field									5					5				5
<u>Operational Systems</u>																		
Earth and Ocean Dynamics Monitors														3				3

*SEASAT-B. Prototype operational ocean dynamics monitor satellite. Last mission in current EOPAP plan. Could be launched by Shuttle with propulsion stage or Tug.

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MATERIALS PROCESSING AND SPACE MANUFACTURING WORKING GROUP

EXECUTIVE SUMMARY

The three principal resources that space flight affords for work in materials science and technology are virtual weightlessness, a vacuum sink of unlimited capacity, and energy in the form of solar radiation. Weightlessness is the most important of these resources, since it cannot be duplicated on Earth for more than a few seconds. Prospects for its exploitation include processing of levitated solids and liquids, production and manipulation of mixtures that are not stable in normal gravity, and processes utilizing the enhanced control over heat and mass transfer that is made possible by the convectionless behavior of weightless fluids. Space vacuum and solar radiation are primarily useful as sources of needed utilities, although there is some prospect that wake effects can be used to achieve ultrahigh vacua in large volumes at low orbital altitudes.

The Working Group has identified a wide variety of research and development topics in which space experiments could make useful contributions to metallurgy, semiconductor and electronic materials technology, medical and biological applications, ceramic and glass technology, and fluid physics and chemistry. It is believed that space efforts in these areas can lead to valuable advances in process technology for use on the ground by showing how to control effects due to gravity that cannot be isolated by methods available on Earth. In addition, it is expected that space research and development may lead to manufacturing processes for valuable products that can only be produced in space.

The community that shares interests in the areas of materials science and technology outlined above is worldwide, extremely large and varied, and intimately involved with large-scale industry. Therefore, it is expected that a large user community can be developed for space processing activities very early in the Shuttle/Sortie Lab. flight program, and that user organizations will wish to invest in space research for proprietary purposes as soon as its value has been demonstrated. In order to explore the wide range of potential interests more fully and begin the mobilization of user interest in the exploitation of the Shuttle/Sortie Lab. system, the Working Group strongly recommends that NASA should follow up on its activity by forming a broadly representative advisory group from the scientific and industrial communities to develop comprehensive recommendations for the Space Processing Program.

The Working Group recommends that NASA should plan for a Shuttle Sortie experiment program involving at least 100 investigators in order to give reasonable coverage to the research and development areas identified in its report. It is also recommended that the program should concentrate on making space easily accessible to the international scientific and industrial community and on developing capable research and development techniques in its early phases, with a view to building up a flow of useful results and identifying specific prospects for space manufacturing in a few years. It is anticipated that some promising processes may be ready for reduction to manufacturing practice in space by the middle 1980's.

Because the experiment program must serve a large user community at moderate cost, the Working Group recommends that space processing payloads should be made up from an inventory of general purpose laboratory equipment that the experimenters can use in common. This will necessitate equipment designs that permit individual items of apparatus to be assembled with each other very flexibly to configure payloads for specific groups of experiments, and will also require a continuing program of apparatus maintenance and modification on the ground. For reasons of economy it will be necessary to design apparatus systems for maximum productivity in flight, and it is believed that this will require that operations should be performed under automatic control wherever possible. Heat treating operations seem especially amenable to automation and can probably be performed without direct human intervention in unpressurized payload bay space.

In general, space processing payloads are expected to be constrained by the availability of power and heat rejection capacity rather than size, weight, or crew availability. If the recommended approach to payload design is followed, it should be possible to configure small payloads to fit available resources and carrying capacity on virtually every Shuttle mission. Frequent flights of small payloads would somewhat relax the constraints due to power and heat rejection requirements and would probably be the most efficient way of serving the large and diverse user community that the Working Group envisions. Moreover, sharing of missions with other payloads could obviously help toward the attainment of maximum Shuttle utilization and operating economy. However, it is estimated that the minimum requirements of the recommended program could be approximately satisfied by four dedicated sortie missions per year with payloads that would fit within the foreseeable resources of the Shuttle/Sortie Laboratory system.

SPACE TECHNOLOGY WORKING GROUP

EXECUTIVE SUMMARY

The Space Technology Shuttle Payload Program offers the potential of major multi-flight facilities that combine significant elements of low cost, broad participation and innovative management concepts. Elements of the program are summarized below:

Long Duration Exposure Facility—a 30 foot long by 14 foot diameter module that will be placed in orbit by the Shuttle, remain in orbit for about six months, retrieved by the Shuttle and returned to earth. The module will expose more than 1300 ft² of passive experiments to the synergistic effects of the space environment and requires no orientation, telemetry or power. As a facility, the module can be refurbished with hundreds of new experiments, in 4 ft x 6 ft panels, after each flight and flown again and again. This facility represents the epitome of low cost and will engender a maximum participation from the technical communities of the world. Anything that requires exposure to space - solar cells, thermal coatings, materials, sealants, microbes, seedlings, storage containers, etc., can be assembled into standard 4 ft x 6 ft panels, placed on the module for exposure and returned to the investigator for inspection on the ground after return from orbit. Because of its simplicity and low cost, the Long Duration Facility is currently planned as the payload for one of the first preoperational Shuttle orbital flights, to verify Shuttle deployment of a satellite, and on subsequent flights to verify Shuttle refurbishment and satellite retrieval techniques.

Advanced Technology Laboratory (ATL)—an experiment carrier that will be compatible with the Sortie Laboratory and will permit any NASA center to extend its laboratory programs into space. In this program LaRC will design and build a flight experiment carrier upon which it will mount, integrate and check a group of interdisciplinary experiments which are derived from and extend technology investigations that are part of the LaRC laboratory effort. Typical experiments include an investigation of the effects of the space environment on material fatigue life and fatigue crack propagation (sponsored by OAST) a determination of elemental abundances in meteoroids from uv meteor spectroscopy (sponsored by OSS) and measurements of atmospheric constituents and pollutants using a tunable laser (sponsored by OA). The experiment carrier, complete with checked-out experiments can then be shipped to the launch site for insertion into the Sortie Laboratory and then flown on the Shuttle. LaRC implementation of the concept will provide the design of the experiment carrier and a ground based Sortie Lab - ATL interface, demonstrate the feasibility and low cost potential of Center autonomy in the development and integration of interdisciplinary and inter-Program Office payloads, and will evolve the necessary innovations in management procedures. Definition of the Advanced Technology Laboratory must be in parallel with the progress on the Sortie Laboratory in order to ensure compatibility; one

immediate effect has been the preliminary selection of a complete end enclosure on the Sortie Lab rather than a 5 ft diameter opening, in order to permit insertion of the experiment carrier. A potential effect is possible inclusion of the experiment carrier as an element of the Sortie Lab development. In this case, LaRC would procure the already developed experiment carrier and procede with the ATL from that point.

Physics and Chemistry Laboratory—a grouping of facilities that will provide the capability for investigations in fundamental physics and chemistry that cannot be accomplished on the ground. As differentiated from research on space (OSS) and research from space (OA), the weightlessness of orbital flight and the infinite vacuum sink of space will be exploited for doing research in space. Areas of research that have been tentatively identified include superfluidity, droplet dynamics, fluid flow and heat transfer, phase change phenomena and gas/molecular beam chemistry. The initial phase of the program is devoted to identification of specific investigations of significant interest to the scientific community. Subsequent phases of the program will define a sufficient number of these investigations to determine feasibility and to identify associated experiments, will group the investigations in accordance with mutual facility requirements (such as a gas chemistry facility) and will design and develop facilities for flight on an individual facility basis or as a dedicated laboratory, depending upon cost effectiveness.

The Physics and Chemistry program will provide a new area of space exploitation and will afford the opportunity to involve new segments of the scientific community on an international scale.

Contamination—a program in support of the Shuttle and Shuttle payloads, to provide real time measurement of the contamination environment and to develop a definitive model of the contamination problem. An Integrated Real Time Contamination Monitor (IRTCM) is being developed that will accompany virtually every Shuttle flight and that will provide immediate data on the extent of gaseous and particulate contaminants, the composition, the light scattering, the rate of deposition and the direction. The use of this instrumentation will also make it possible to implement an experiment in which known contaminants will be released so that the Shuttle contamination problem and theoretical models of contamination can be specifically verified.

Laser Information/Data Transmission—a major engineering experiment designed to verify laser information/data transmission technology in low earth orbit. In conjunction with a laser system on a synchronous satellite (similar to the OAST experiment that was being developed for flight on the cancelled ATS-G), the Shuttle laser experiment would verify the technology of a laser relay satellite system.

Following acquisition of sufficient experiment data the system will have operational potential for possible enhancement of Shuttle data transmission capabilities. Although this is the only major engineering system experiment now being defined, it is anticipated that additional ones such as laser power transmission and advanced Shuttle reentry configurations will be added to the program.

